Documentation of Aquifer Tests Conducted at Hanger 1000, Jacksonville Naval Air Station, Jacksonville, Florida

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Documentation of Aquifer Tests Conducted at Hanger 1000, Jacksonville Naval Air Station, Jacksonville, Florida

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SUMMARY OF AQUIFER TEST RESULTS:

Well MW-3

Analytical Method:	Moench Method
Pumping rate =	0.64 gpm
Transmissivity =	110 ft^2/d
Horizontal hydraulic conductivity =	8 ft/day

Well MW-10

Analytical Method:	Moench Method
Pumping rate =	0.45 gpm
Transmissivity =	61 ft^2/d
Horizontal hydraulic conductivity =	4 ft/day

Well MW-26

Analytical Method:	Cooper-Jacob Method
Pumping rate =	0.25 gpm
Transmissivity =	1.2 ft^2/d
Horizontal hydraulic conductivity =	0.2 ft/day

INTRODUCTION

Aquifer tests were conducted on monitoring wells MW-3, MW-10, and MW-26 located at Hanger 1000 of the Jacksonville Naval Air Station, Jacksonville, Florida. The purpose of the aquifer testing was to determine the hydraulic properties of the surficial aquifer at this site. Well locations are shown on figures 1 and 2. A description of the wells is given in table 1. The purpose of this report is to document the aquifer tests and present the analyses of the data. The raw field data and processed data are contained on a CD-ROM disk accompanying the report.

The surficial aquifer at the site consists of a combination of inter-bedded fine sands, silts, and clays. A composite lithologic log is shown in table 2 and a geologic cross-section is shown in figure 2. Underlying the surficial aquifer is the very low permeability Hawthorn Formation; underlying the Hawthorn Formation is the Floridan Aquifer.

Table 1. Characteristics of wells used for aquifer testing at Hanger 1000.

[a: Relative to the National Geodetic Vertical Datum of 1929]

Well name	Depth, in feet	Screen length, in feet	Diameter, in inches	Top of casing, in feet[a]
MW-3	14	10	4	16.40
MW-10	12	10	4	16.37
MW-11	34	5	4	16.35
MW-26	25	5	2	9.50
MW-27	14	10	2	9.70
HD10-D3	58	5	2	unk

Table 2. Generalized lithologic log for Hanger 1000

Depth	Lithology
0’-20’	Silty sand
20’-24’	Dark gray sand w/silt and clay
24’-24’ 2"	2" Dark gray clay
24'2”-27'	Dark gray sand, silt, clay mixture
27' - 28'	Dark gray sand, silt, clay mixture w/some shells
28' - 32'	Dark gray clay w/sand and silt
32' - 36'	Dark gray clay w/shells
37' - 41'	Dark gray clay with shells (clay stiff and dry)
41' - 44'	Dark gray clay with shells (clay stiff and dry)
44' - 47'	Dark gray clay with shells (clay stiff and dry)
48' - 51'	Dark gray clay with shells (clay stiff and dry)
51' - 54'	Dark gray clay with shells (clay stiff and dry)
54' - 55'	Light green, medium to fine sand
55' - 56'	Light green, medium to fine sand w/silt
56' - 57'	Light green, medium to fine sand w/silt and clay
57' - 58'	Light green, medium to fine sand w/silt and clay

Water levels were measured using Solinst Levelogger series pressure transducers and were checked periodically by hand measurements using an electric or steel tape. Some of the aquifer tests were analyzed using Aquifer Test for Windows, version 2.56, by Waterloo Hydrogeologic, Inc.

MONITORING WELL MW-3 AQUIFER TESTS

Three separate aquifer tests were conducted on monitoring well MW-3: a step-drawdown test, a constant rate pumping test, and a slug test. Drawdown was measured only in the pumping well. Three tests were conducted because each method measured permeability in slightly different way, and it was hoped that the combination of tests would aid in determining the best estimate of hydraulic conductivity. This well is screened across the water table of the unconfined aquifer.

Step-Drawdown Test

The step-drawdown test was conducted to determine the efficiency of the well. The well was pumped at three different rates: 0.54 gallons per minute (gpm), 1.11 gpm, and 2.02 gpm. The drawdowns of the step-drawdown test are shown in figure 3. Table 3 shows the pumping rate, drawdown, and the ratio of the drawdown divided by the pumping rate for each step. Figure 4 shows a plot of the data from Table 3. From this plot the drawdown can be separated into two components: the drawdown due to laminar flow and the drawdown due to turbulent flow using the method described by Bierschenk (Bierschenk, 1964). The laminar flow component is attributed to the aquifer and the turbulent flow component is attributed to loses due to the well construction. The equation below relates the drawdown to the two components:

$$S_w = BQ + CQ^2$$

Where: S_w = Drawdown, in ft,

B = formation loss coefficient (and is the Y axis intercept at X = 0 on figure 4), in ft/gpm,

Q = pumping rate, in gpm,

C = well loss coefficient (and is the slope of the line on figure 4), in ft/gpm^2.

Table 3. Pumping, drawdown, and drawdown divided by the pumping rate for well MW-3.

Pumping rate, in gpm	Drawdown, in feet	Drawdown/Pumping rate, in feet per gpm
0.54	0.70	1.30
1.11	1.47	1.32
2.02	2.76	1.37

The BQ term is drawdown in the well due to laminar flow and the CQ^2 term is the drawdown due turbulent flow. Substituting in the coefficients and pumping rate gives the following equation:

$$S_w = (1.260 \text{ ft/gpm}) (2.02 \text{ gpm}) + (0.054 \text{ ft/gpm}^2) (2.02 \text{ gpm})^2$$

$$S_w = 2.54 \text{ ft} + 0.22 \text{ ft} = 2.76$$

Based on this analysis, at a pumping rate of 2.76 gpm the drawdown in the aquifer due to laminar flow is 2.54 ft and in the well due to turbulent flow is 0.22 ft. The efficiency of the well (E) at a pumping rate of 2.02 gpm is given by the formula:

$$E = 100 \text{ x } (BQ/S_w) = 100 \text{ x } (2.54 \text{ ft} / 2.76 \text{ ft}) = 92\%$$

The following equation from Lohman (1979) was solved using the highest pumping rate of the step-drawdown test, 2.02 gpm, the resulting drawdown in the aquifer of 2.54 feet after 1 hour (2.54 ft of drawdown occurred in the aquifer and 0.22 ft occurred in the well for a total drawdown of 2.76 ft), and assuming a specific yield of 0.2 to determine a transmissivity of 69 ft^2/day. The specific yield in silty sands can range from 0.1 to 0.3 (Johnson, 1967). If the specific yield were 0.1 the transmissivity determined would be slightly higher and a value of 0.3 would result in a slightly lower transmissivity.

$$\frac{Q}{s_w} = \frac{4\pi T}{2.30 \log \frac{2.25 Tt}{r_w^2 S}}$$

Where: Q= pumping rate, in ft^3/day
T= transmissivity, in ft^2/day
s_w = drawdown in the pumped well, in feet
t = time, in days,
r_w= radius of the well, in feet,
S= specific yield, no units

The parameter u was calculated to be 0.0012; values for u less than 0.01 indicate that a steady rate of decline in drawdown has been achieved, and this in turn indicates that the specific capacity and Cooper-Jacob methods can be applied without significant error due aquifer storage.

Constant Rate Test

During the constant rate test, well MW-3 was pumped at 0.64 gpm for 2 hours. This test was analyzed using the method described by Moench (1993) and the results of the analysis are shown in figure 5. A transmissivity of 110 ft^2/day and a hydraulic conductivity of 8 ft/day were determined. In figure 5, the lower curve labeled “Theis (Sy)” is the Thies curve, the upper curve labeled “MW3 transducer” is the same curve only it has been displaced upward by the Moench method to account for the partial penetration of well MW-3 in the aquifer. The data was matched to this curve. The transmissivity of 110 ft^2/day and hydraulic conductivity of 8 ft/day apply to the full thickness of the aquifer.

Slug Test

A slug test was also performed on well MW-3 and the results of the test are shown in figure 6. This test was analyzed using the Bower and Rice method (1976) and a hydraulic conductivity of 4 ft/

day was determined.

Discussion

The transmissivity of 110 ft^2/day and hydraulic conductivity of 8 ft/day determined by the Moench method probably represents the best estimate of the aquifer properties. This is because the Moench method corrects for the fact that this well penetrates approximately half the thickness of the aquifer.

The specific capacity method gave a transmissivity of 69 ft^2/day. However, this value is probably less than the true value because the ground water, as it nears the well, is forced to flow through only the upper half of the aquifer. Restricting the flow to half the aquifer will increase the drawdown and result in a lower calculated transmissivity value.

The slug test gave a value of 4 ft/day. Why this method gave a lower hydraulic conductivity value than the constant rate test is not clear, but the constant rate test involved pumping the well (and thus moved a significantly larger volume of water through the aquifer) and probably represents a better estimate of the actual hydraulic conductivity of the aquifer. However, both estimates of hydraulic conductivity fall within the range of expected values for these sediments as shown tables 4 and 5.

Table 4. Ranges of hydraulic conductivity values for unconsolidated deposits (after Freeze and Cherry, 1979)

Aquifer Material	Lower range of hydraulic conductivity, in ft/day	Upper range of hydraulic conductivity, in ft/day
Gravel	3×10^{2}	3×10^{5}
Clean sand	3×10^{0}	3×10^{4}
Silty Sand	3×10^{-2}	3×10^{2}
Silt	3×10^{-4}	3×10^{0}
Marine clay	3×10^{-4}	3×10^{-12}

Table 5. Average values of hydraulic conductivities (after Lohman, 1979)

Material	Average hydraulic conductivity, in ft/day
Coarse gravel	1,000
Medium gravel	950
Fine gravel	900
Very coarse sand	700
Coarse sand	250
Medium sand	50
Fine sand	15

MONITORING WELL MW-10 AQUIFER TEST

A single constant rate pumping test was performed on well MW-10. This test was analyzed using the method described by Moench (1993) and the results of the analysis are shown in figure 7. A transmissivity of 61 ft^2/day and a hydraulic conductivity of 4 ft/day were determined. In figure 7, the lower curve labeled "Theis (Sy)" is the Thies curve, the upper curve labeled "Well MW10" is the same curve only it has been displaced upward by the Moench method to account for the partial penetration of well MW-10 in the aquifer. The data was matched to this curve. The transmissivity of 61 ft^2/day and hydraulic conductivity of 4 ft/day apply to the full thickness of the aquifer.

MONITORING WELL MW-26 AQUIFER TESTS

Two single well aquifer tests were conducted on monitoring well MW-26. One was a constant rate pumping test and the other a slug test. A step-drawdown test was attempted but excessive draw-down at the lowest pumping rate made conducting this type of test infeasible. This well is screened approximately 20 feet below the water table and in the deeper, lower permeability sediments present in the Hanger 1000 area. The aquifer adjacent to the screened interval is considered to be confined at this well location.

Constant Rate Test

The well was pumped at 0.25 gpm for 3 hours. This test was analyzed using the Cooper-Jacob method (1946) and the results are shown in figure 8. At about 140 minutes into the test the water level in the well dropped below the pressure transducer (the range of the transducer did not allow it to be set deeper) although the hand measurements continued. In figure 8 both the hand measurements and the first 140 minutes of the transducer data are plotted. The measured pumping rate ranged from 0.12 to 0.40 gpm, it was particularity difficult to keep a consistent pumping rate during this test.

It was assumed that this well was screened in a higher permeability zone within the overall low-permeability clay layer. It was further assumed that this zone was 5 ft height, the same length as the well screen. Well MW-27, located immediately adjacent to MW-26 and screened across the water table, did not respond to the pumping in MW-26. This indicates that the zone pumped in MW-26 was not vertically connected to the shallower part of the aquifer. A transmissivity of 1.2 ft^2/day and hydraulic conductivity of 0.2 ft/day were determined. The parameter u was calculated to be 1×10^{-5}, values for u less than 0.01 indicate that a steady rate of decline in drawdown has been achieved, and this in turn indicates that the Cooper-Jacob method can be applied without significant error due aquifer storage.

Slug Test

A slug test was also performed on well MW-26 and the results of the test are shown in figure 9. This test was analyzed using the Bower and Rice method (1976) and a hydraulic conductivity of 0.2 ft/day was determined.

Discussion

During the slug test the water level in the well returned to the pre-test level in about 24 minutes, this indicates that the well is probably in good hydraulic connection with the aquifer. However, after the pumping test (which lasted 3 hours) the water level did not returned to pre-test levels. At 8 hours and 27 minutes after the pumping stopped the water level was still 0.55 ft below the pre-test level. This combination of facts may indicate that the well is screened in a higher permeability zone that is isolated within the overall clay layer. And that the pumping removed more water from the zone than the surrounding clay could recharge in the period after the pumping stopped.

Both of these test gave a hydraulic conductivity of 0.2 ft/day. This value falls within the expected range as shown in table 4.

REFERENCES

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Bierschenk, W. H., 1964, Determining well efficiency by multiple step-drawdown tests: Intl. Assoc. Sci. Hydrology Publ. 64. p. 493-507

Cooper, H. H. and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history: Trans. Amer. Geophysical Union, v. 27, pp. 526-534, 1946

Freeze, R. A., and Cherry, J.A., 1979, Groundwater, Prentice-Hall, Inc., 604 p.

Johnson, I. A., 1967, Specific yield-compilation of specific yields for various materials: U.S. Geological Survey Water-Supply Paper 1662-D, 74 p.

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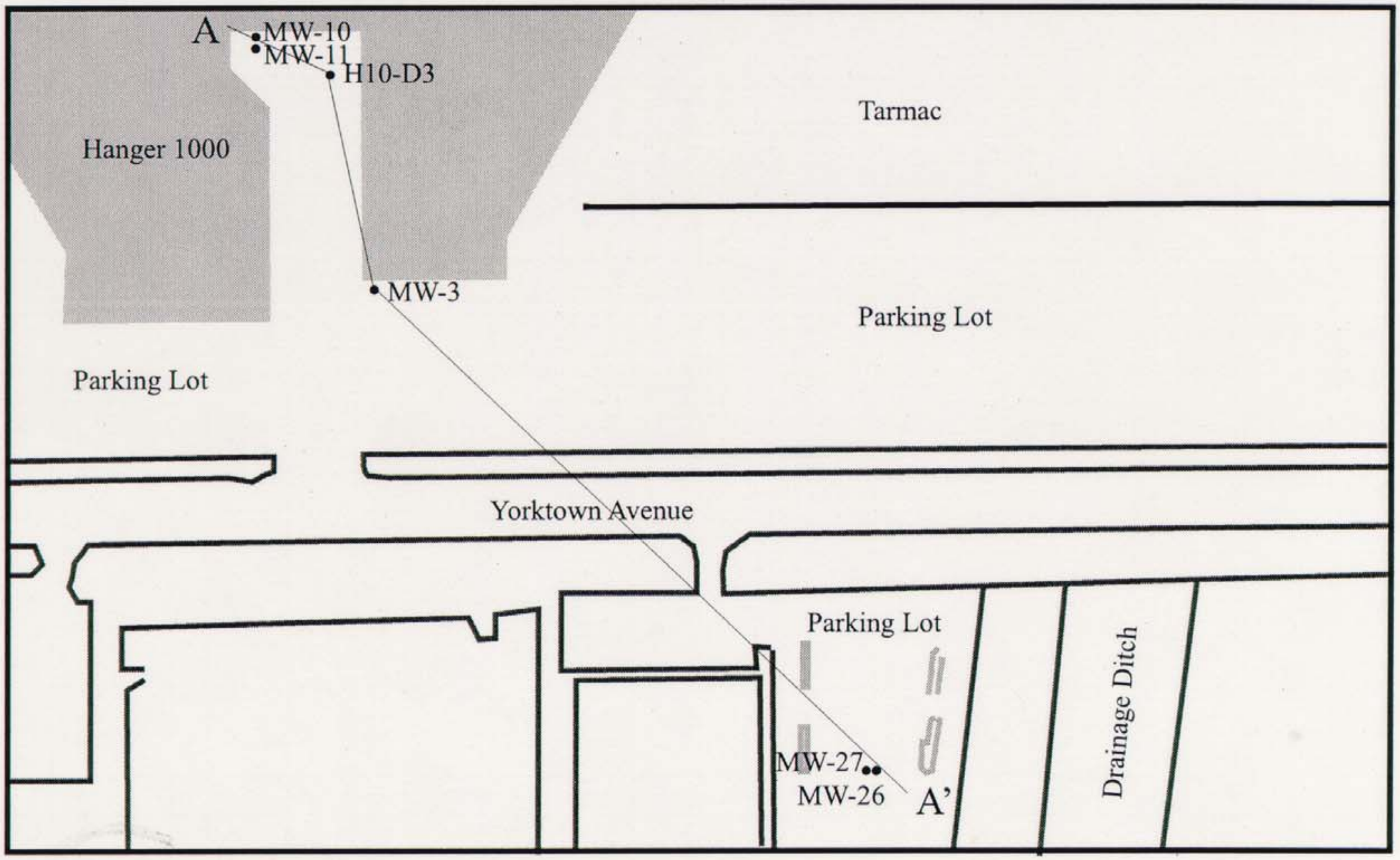
Moench, A. F., 1993, Computation of type curves for flow to partially penetrating well is water-table aquifers: Ground Water, Vol. 31., No. 6, p. 966-984



Note: Only wells discussed in this report are shown on the map, other monitoring wells located at the facility are not shown.

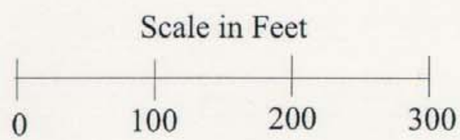


Figure 1. Location of wells used for aquifer testing.

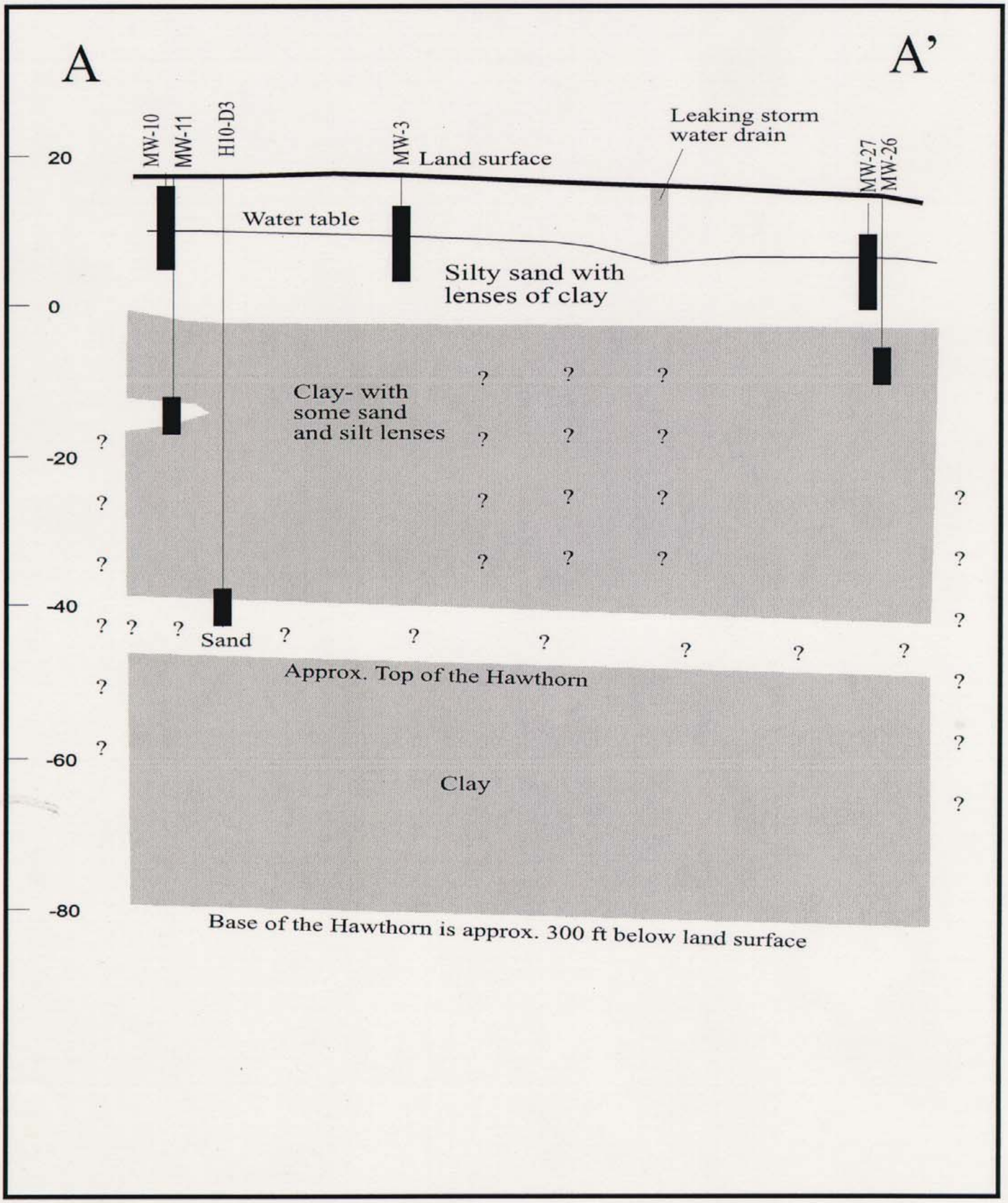


Figure 2. Generalized geologic cross-section for Hanger 1000.

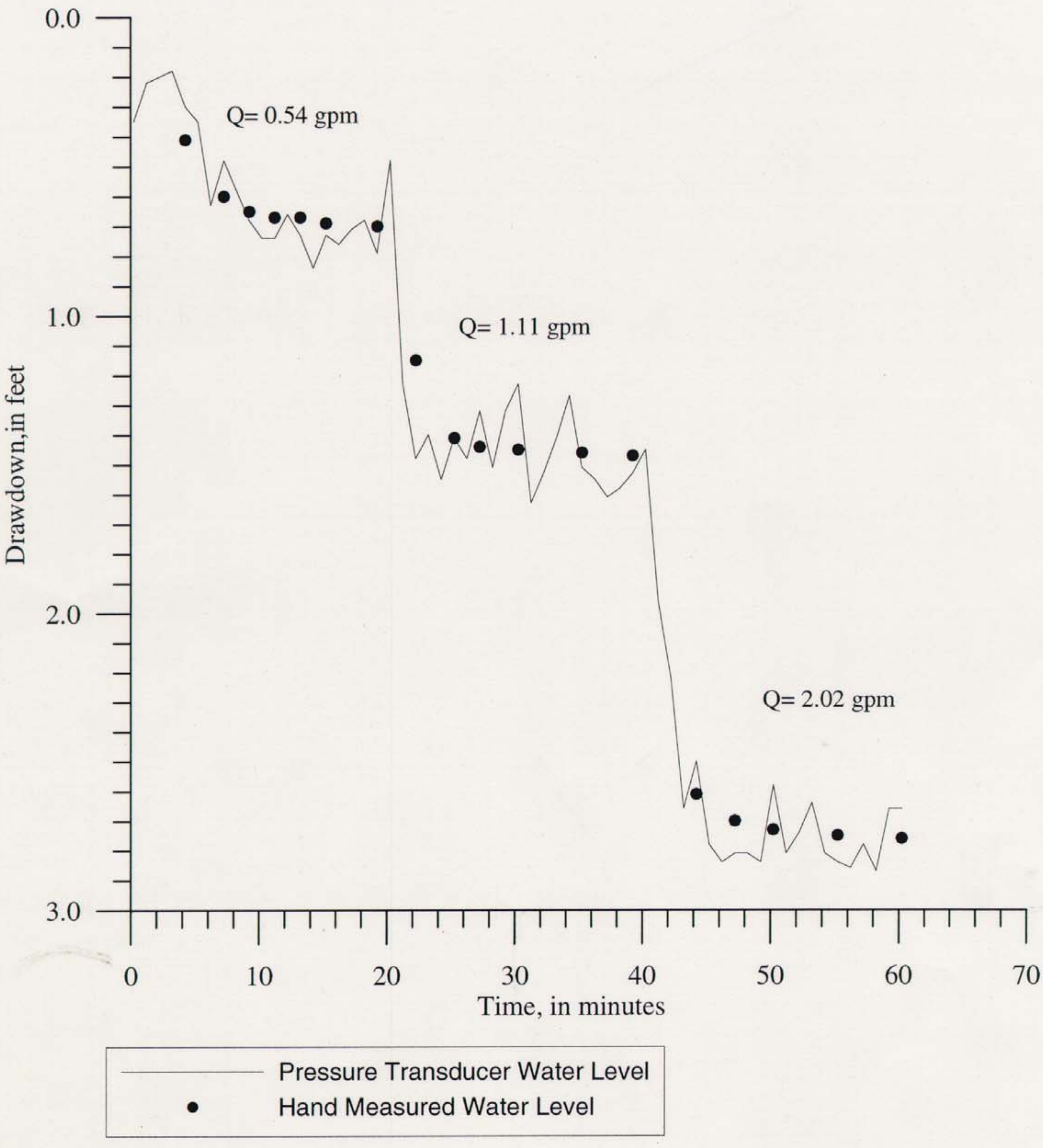


Figure 3. Water-level changes during the MW-3 step-drawdown test.

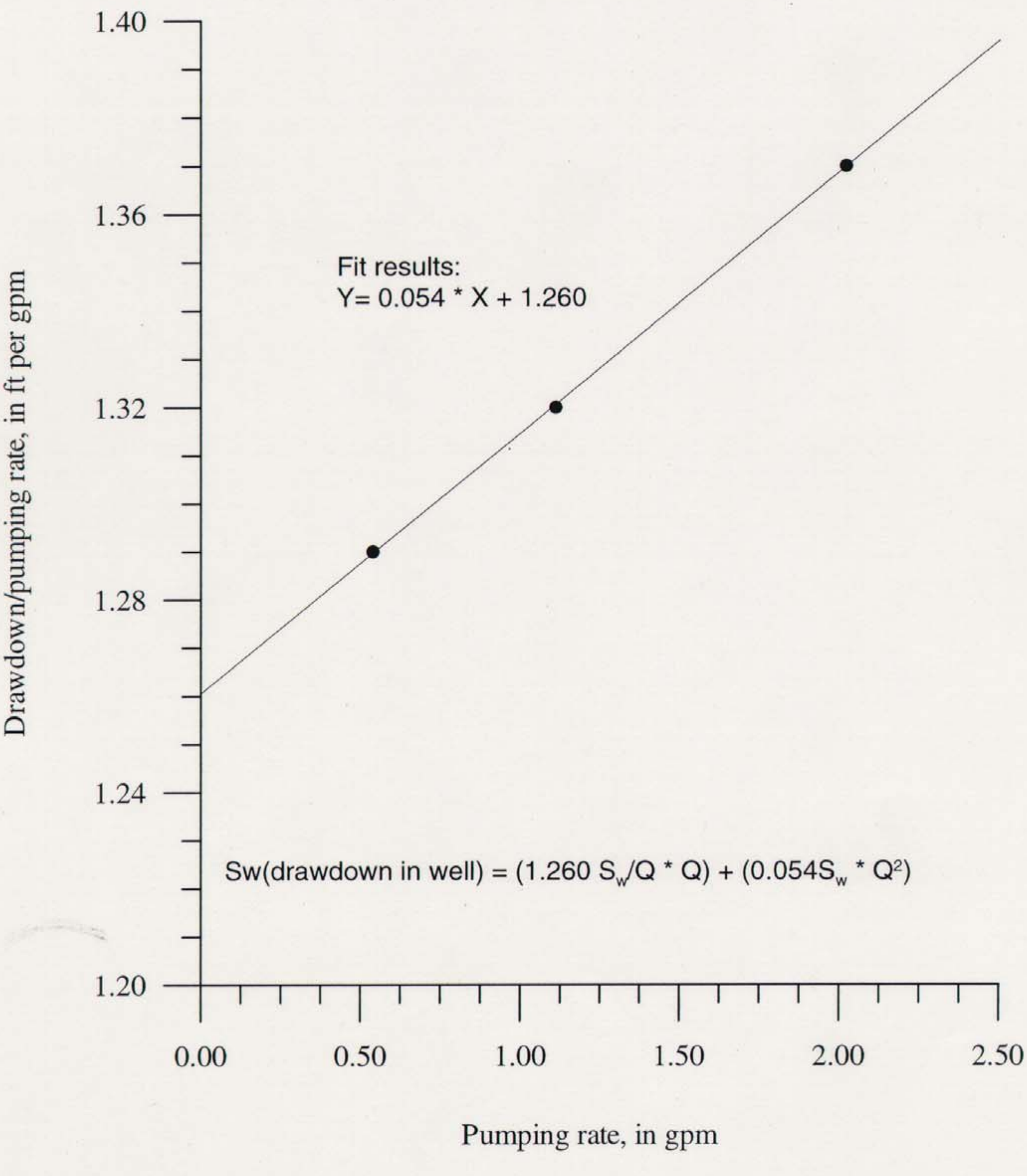
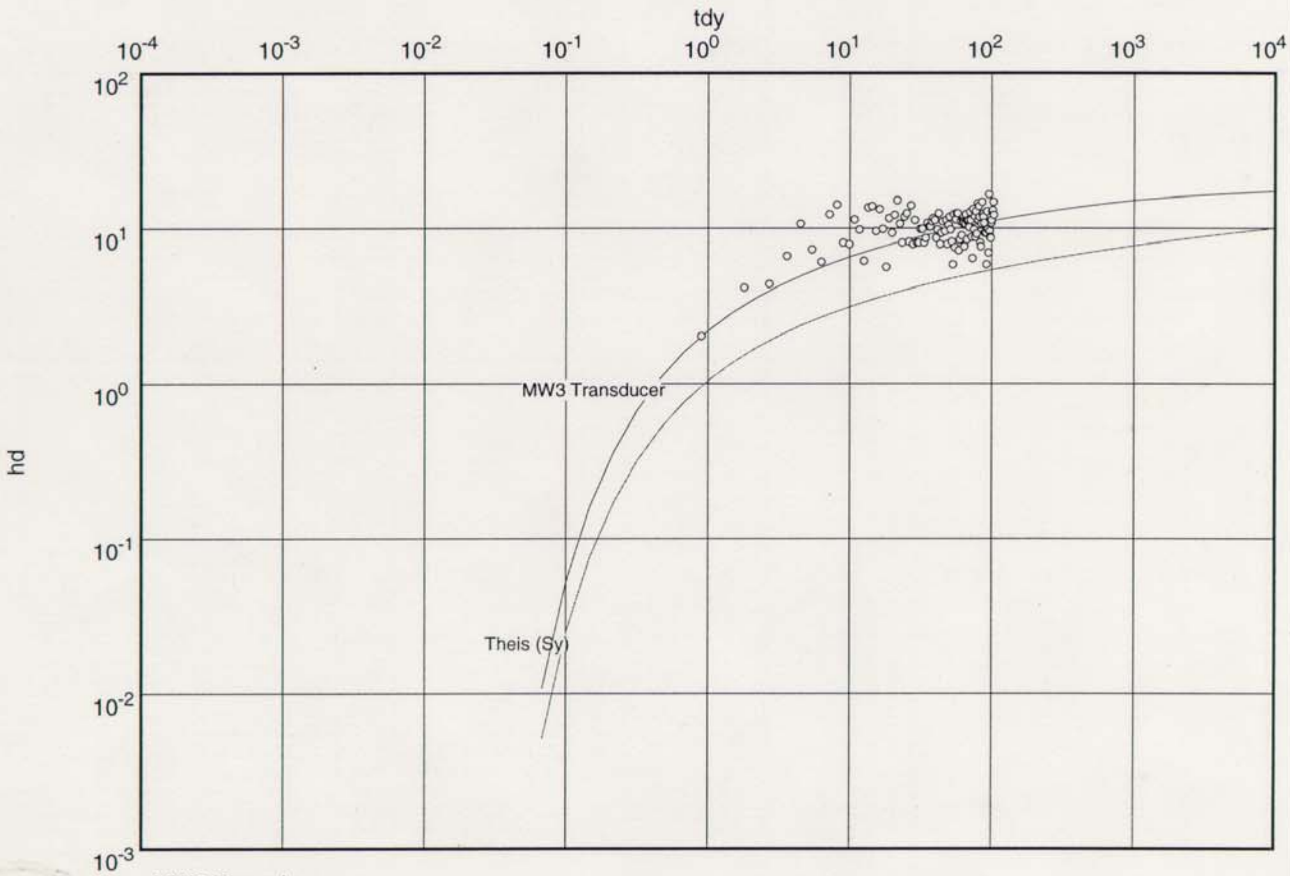


Figure 4. Plot of pumping rate vs. drawdown divided by pumping rate for the MW-3 step-drawdown test.

Waterloo Hydrogeologic 180 Columbia St. W. Waterloo,Ontario,Canada ph.(519)746-1798	Pumping test analysis MOENCH's method Unconfined aquifer	Date: 18.10.2001	Page 1
		Project: NAS-JAX Hanger 1000	
		Evaluated by: Hal Davis	

Pumping Test No. Constant Rate	Test conducted on: 2/14/2001
MW3	
Discharge 0.64 U.S.gal/min	



o MW3 Transducer

Transmissivity [ft²/d]: 1.10×10^{2}

Hydraulic conductivity [ft/d]: 7.53×10^{0}

Aquifer thickness [ft]: 14.60

Hydraulic conductivity vertical [ft/d]: 7.53×10^{-1}

Figure 5. Results from constant rate pumping test of well MW-3.

Waterloo Hydrogeologic 180 Columbia St. W. Waterloo,Ontario,Canada ph.(519)746-1798	slug/bail test analysis BOUWER-RICE's method	Date: 02.05.2001	Page 1
		Project: Hanger 1000	
		Evaluated by: Hal Davis	

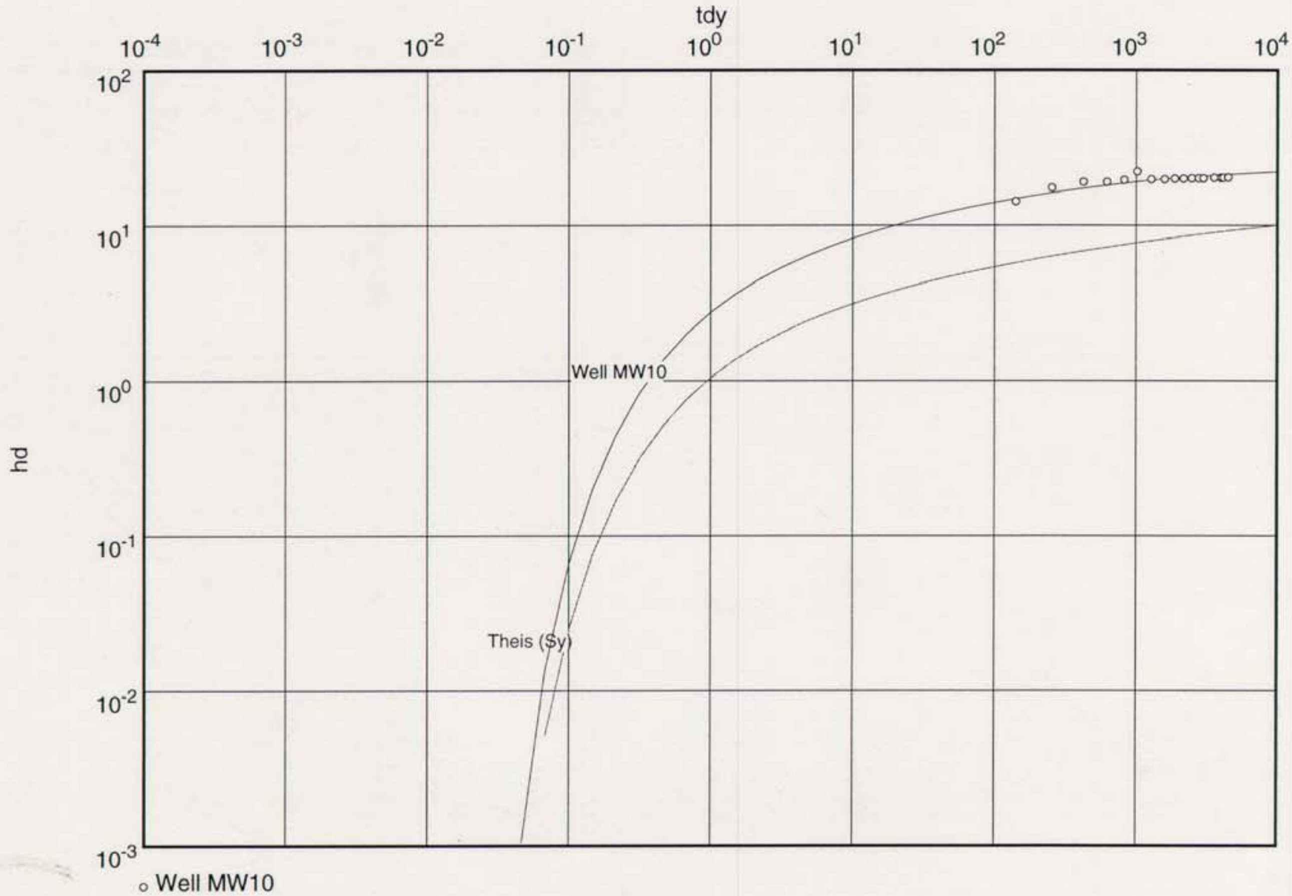
Slug Test No. MW-3	Test conducted on: 2/15/01
MW-3	

Hydraulic conductivity [ft/min]: 2.92 x 1C^3 = 4.2 ft/d

Figure 6. Rising head slug tests results for well MW-3.

Waterloo Hydrogeologic 180 Columbia St. W. Waterloo,Ontario,Canada ph.(519)746-1798	Pumping test analysis MOENCH's method Unconfined aquifer	Date: 02.05.2001	Page 1
		Project: Hanger 1000	
		Evaluated by: Hal Davis	

Pumping Test No. Well MW10	Test conducted on: 2/14/01
Well MW10	
Discharge 0.45 U.S.gal/min	



Transmissivity [ft²/d]: 6.14×10^{1}

Hydraulic conductivity [ft/d]: 4.04×10^{0}

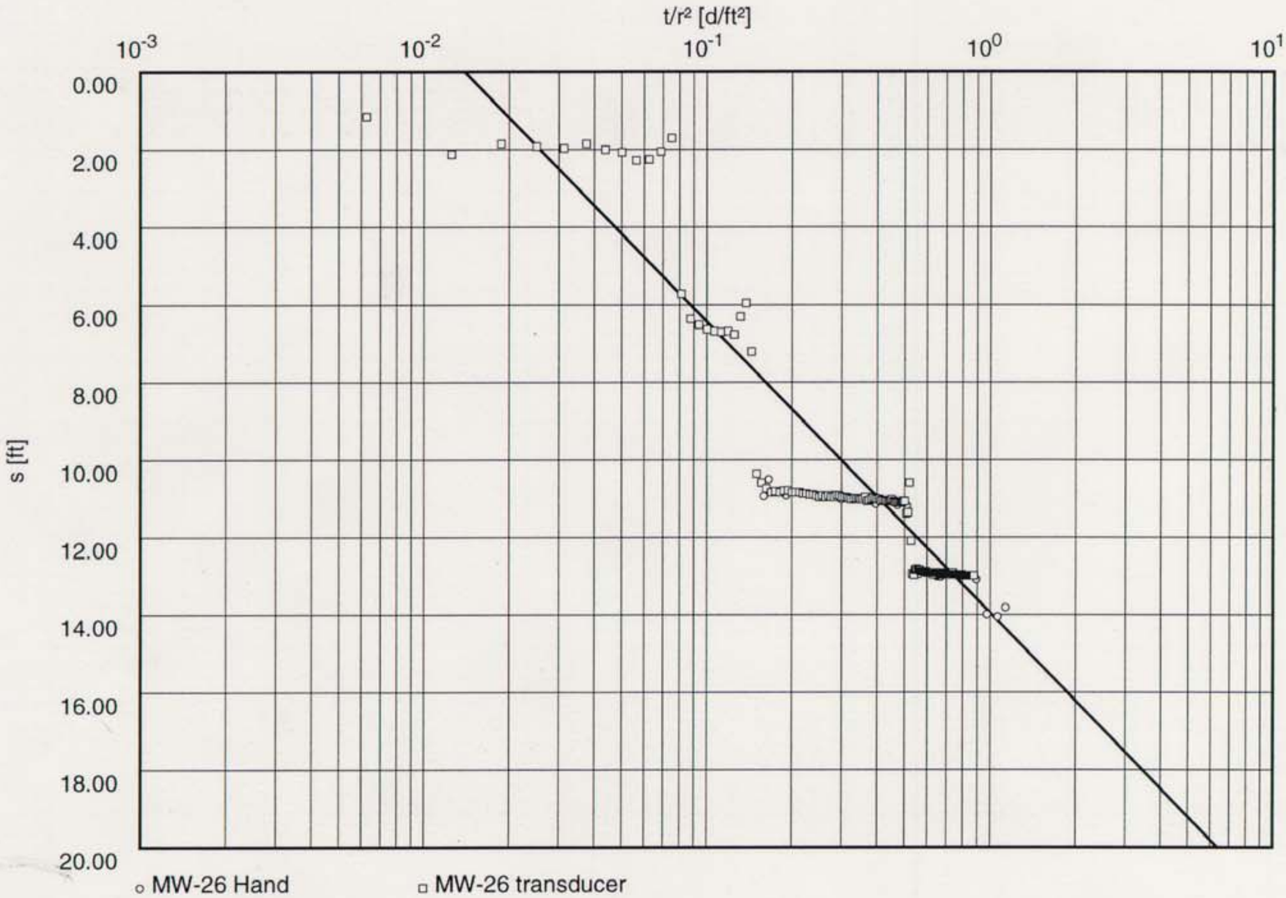
Aquifer thickness [ft]: 15.20

Hydraulic conductivity vertical [ft/d]: 4.04×10^{-1}

Figure 7. Results from constant rate pumping test of well MW-10.

Waterloo Hydrogeologic 180 Columbia St. W. Waterloo,Ontario,Canada ph.(519)746-1798	Pumping test analysis Distance-Time-Drawdown-method after COOPER & JACOB Confined aquifer	Date: 10.05.2001 Page 1 Project: Hangeer 1000 Evaluated by: Hal Davis

Pumping Test No. Well MW-26	Test conducted on: 2/14/2001
Well MW-26	
Discharge 0.25 U.S.gal/min	



Transmissivity [ft²/d]: 1.17×10^{0}

Hydraulic conductivity [ft/d]: 2.34×10^{-1}

Aquifer thickness [ft]: 5.00

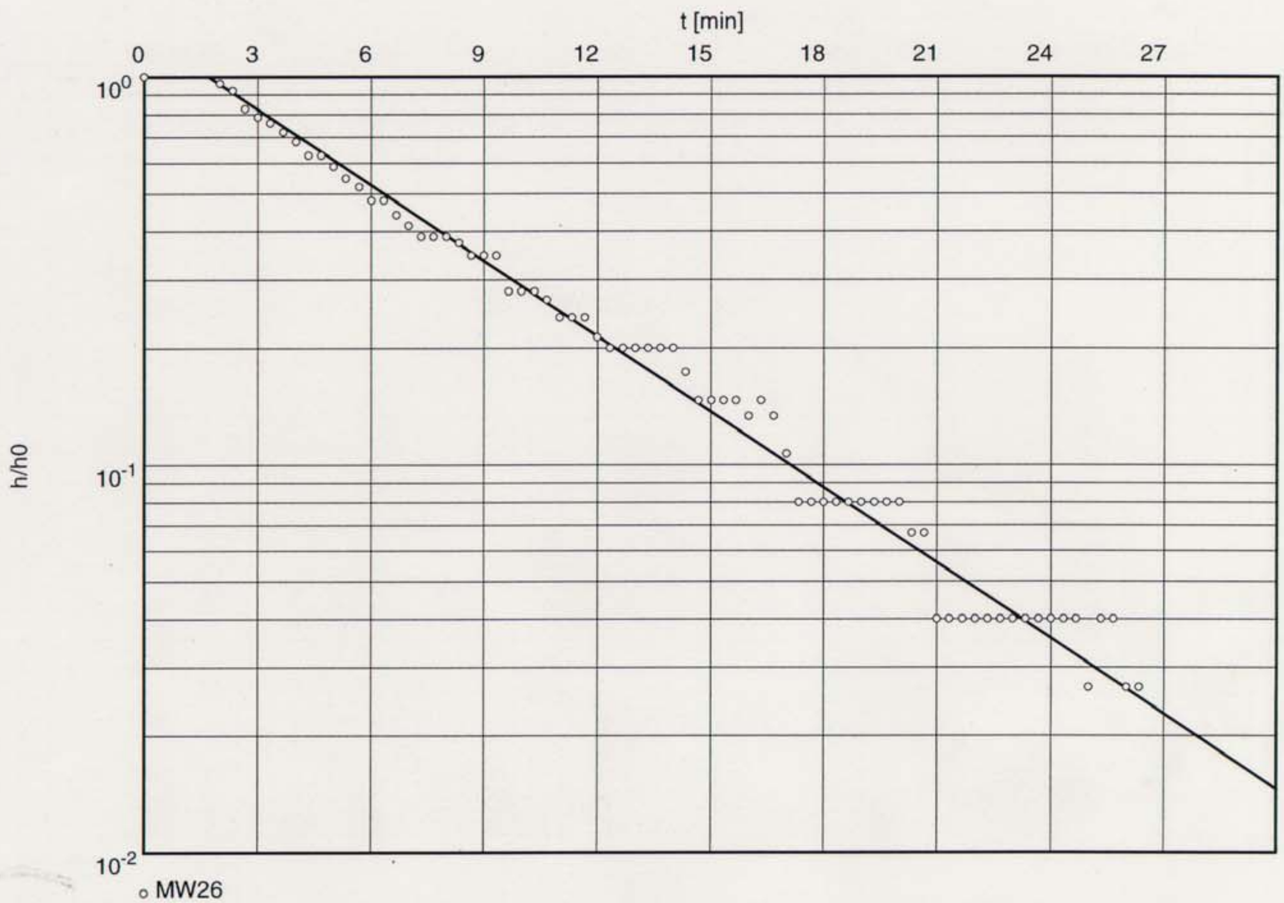
Storativity: 3.66×10^{-2}

Figure 8. Results from constant rate pumping test of well MW-26.

Fig 8

Waterloo Hydrogeologic 180 Columbia St. W. Waterloo,Ontario,Canada ph.(519)746-1798	slug/bail test analysis BOUWER-RICE's method	Date: 16.02.2001	Page 1
		Project: Hanger 1000	
		Evaluated by: Hal Davis	

Slug Test No.	Test conducted on: 2/13/01
Well MW-26	



Hydraulic conductivity [ft/min]: 1.27×10^{-4} = 0,2 ft/d

Figure 9. Rising head slug tests results for well MW-26.